Topic 3.2

What are the Sun and the Moon, and how are they linked to Earth?

Key Concepts

- The Sun is our nearest star.
- Interactions of Earth and the Sun make life possible.
- The Moon is our nearest neighbour in space.
- The Sun, Moon, and Earth interact to create eclipses.

Key Skills

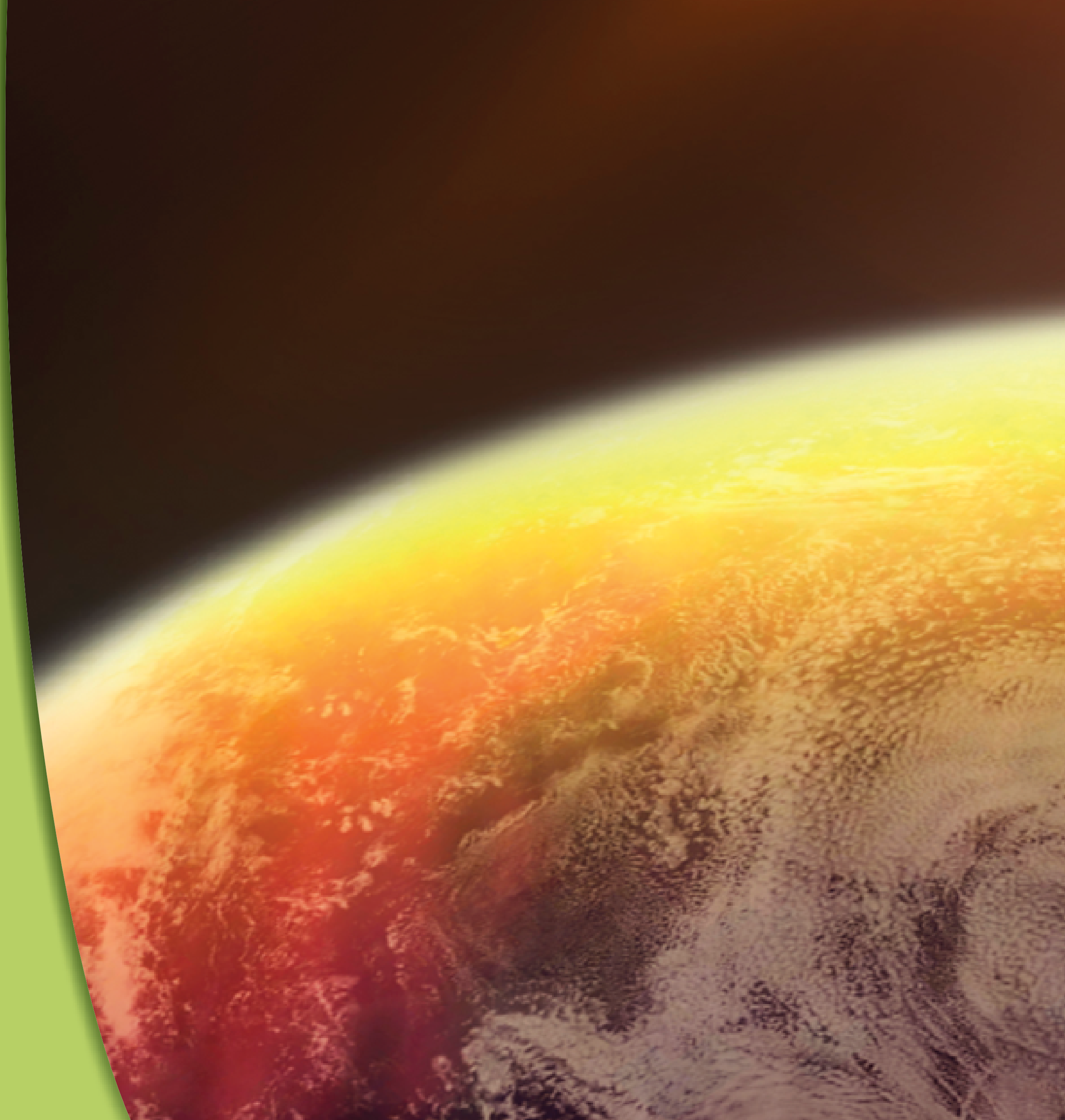
Inquiry
Research

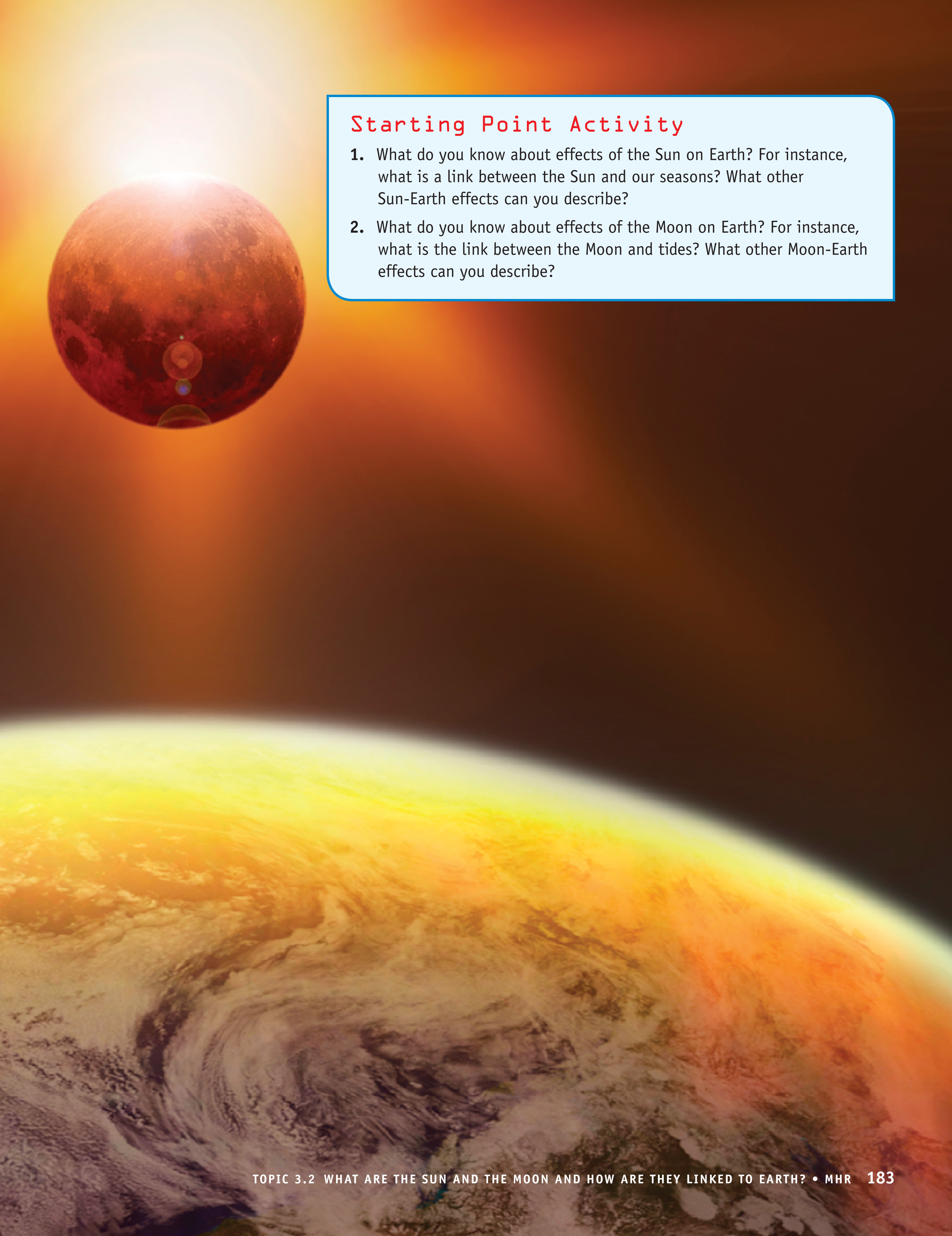
Key Terms

magnetosphere
aurora
solar eclipse
lunar eclipse

We know more about the Sun and the Moon than any other objects in our solar system. One reason for this is that they are the largest objects in our sky, so they are easy to observe and become familiar with. Another reason is that we have sent more satellites and probes to observe and study the Sun and the Moon than all other objects in the solar system combined.

It makes sense for us to know so much about the Sun and Moon. These objects not only inspire the stories we tell, but also affect weather systems, the ways we keep time, and the very existence of life on Earth.





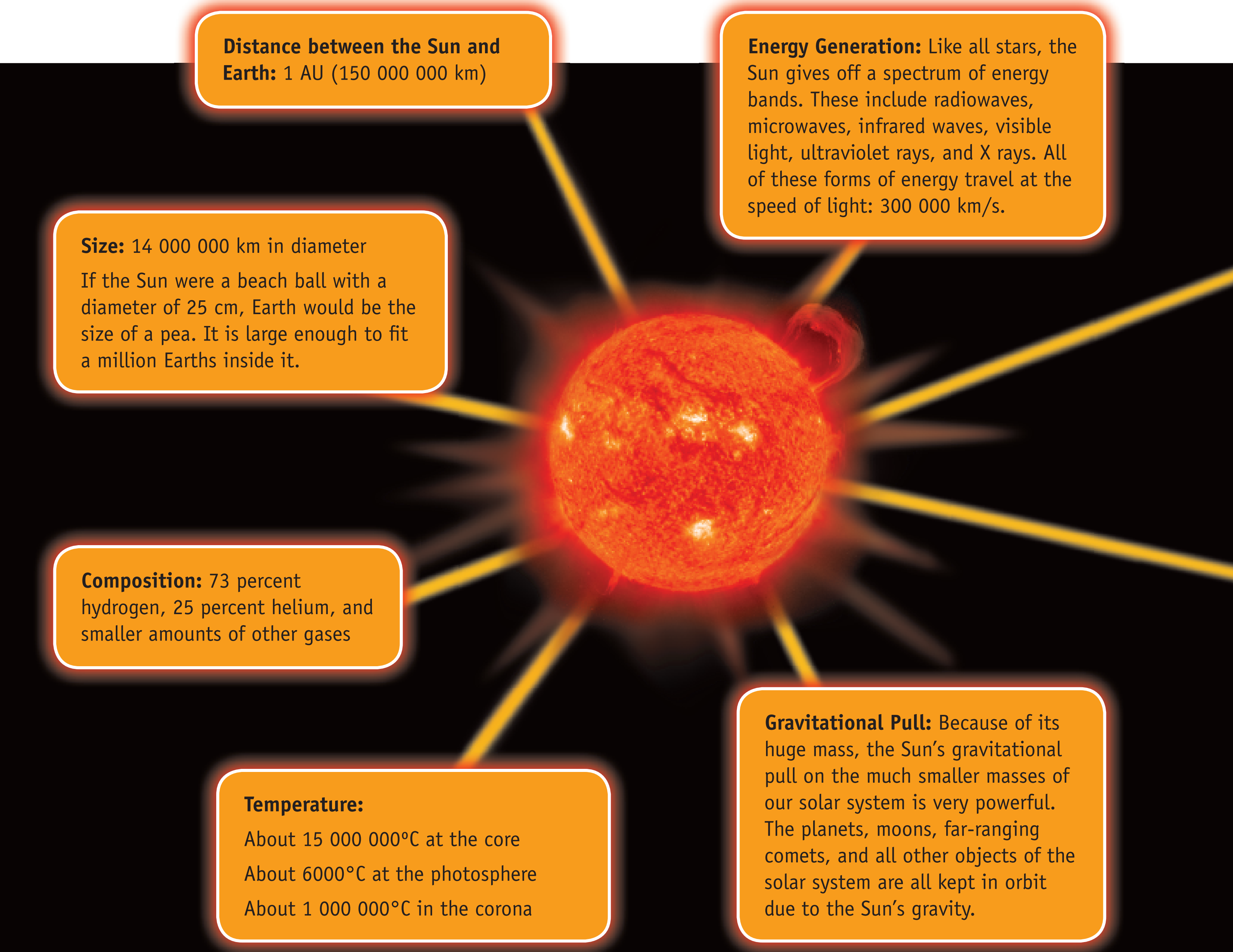
Starting Point Activity

1. What do you know about effects of the Sun on Earth? For instance, what is a link between the Sun and our seasons? What other Sun-Earth effects can you describe?
2. What do you know about effects of the Moon on Earth? For instance, what is the link between the Moon and tides? What other Moon-Earth effects can you describe?

The Sun is our nearest star.

Our Sun, shown in **Figure 3.7**, was born about 5 billion years ago, and will last for another 5 billion years. It contains more mass than 300 000 Earths combined. Strong gravitational forces pull this great mass tightly together, creating great pressure and heat. Under these extreme conditions, hydrogen atoms collide violently with each other, and they combine (fuse). During this process, called nuclear fusion, two hydrogen atoms fuse together to form a helium atom, and great amounts of energy are released.

▼ Figure 3.7 Information about our star, the Sun, is displayed in this photo-based graphic organizer.



How much energy is released? During fusion, each gram of hydrogen releases 90 000 million kJ of energy. That's as much energy as you would get if you ate 1 trillion pizza slices. And that's only for one gram of hydrogen. The Sun has 2.0×10^{33} g (2 000 000 000 000 000 000 000 000 000 000 000 grams) of mass. No wonder the Sun has so much life left in it!

LEARNING CHECK

1. Explain how the Sun produces energy.
2. Use **Figure 3.7** to draw the Sun. Label its temperature, size, and rotation.
3. What is the total expected lifetime of the Sun?
4. Predict why the Sun is part of the sacred traditions of many cultures.

Rotation:

The Sun makes one rotation in 26 days at its equator but takes 37 days to rotate at its poles. (Yes, the Sun rotates faster at its equator than at its poles.)

This ancient symbol for the Sun is also a symbol for the element hydrogen. (See if you can figure out why.)

Research Focus

Activity 3.6

WHAT'S COOL ABOUT THE SUN?

The Sun is much more than just facts about distance, temperature, gravity, and energy. What's cool about the Sun?

Make an idea web like the one used on these two pages. Include spokes for other facts about the Sun. Six options are given below, along with some keywords and hints to help you get started. Add other spokes for other facts that you discover and want to share.

1. Other Features of the Sun: for example, sunspots, coronal mass ejections, flares, solar wind
2. Layers of the Sun (core, photosphere, corona) and their characteristics
3. Telling Time with the Sun: for example, sundials, solar calendars
4. Technology for Studying the Sun: for example, satellites such as IBEX and SOHO
5. The Sun in Song: for instance, what songs feature the Sun in their titles and lyrics?
6. The Sun in Sacred Stories: for example, what are some stories from the sacred traditions of Aboriginal peoples, other cultures, and world religions?

Interactions of Earth and the Sun make life possible.

If Earth's orbit brought us much closer to the Sun, our planet might be a lifeless, scorched desert. If Earth's orbit were much farther away, our planet might be a frigid, icy wasteland. Fortunately, our distance from the Sun is "just right" for life. In fact, astronomers call Earth's position in the solar system the "Goldilocks zone." But being "in the zone" does not guarantee safety from the Sun's energy. Fortunately, Earth's magnetosphere and atmosphere provide the protection needed for life on our planet.

The Link between the Magnetosphere and the Atmosphere

Along with energy, the Sun also sends out streams of matter in the form of charged particles that travel through the whole solar system at great speed. These streams of charged particles are called the solar wind. The solar wind bathes Earth and all other objects in the solar system.

The highly energetic particles of the solar wind are deadly to life. Fortunately, Earth is protected from their effects by a field of magnetic force that surrounds the planet. This field of magnetic force around Earth is called the **magnetosphere**. The magnetosphere deflects the solar wind and prevents much of it from entering the atmosphere.

magnetosphere: the area of space that contains a planet's magnetic field

Charged particles can, however, enter Earth's atmosphere at the poles. At times, especially powerful outbursts of solar wind particles enter at the poles and interact with atoms in the upper atmosphere to create shimmering curtains of beautiful, coloured light. Figure 3.8 shows one such display, which is called an **aurora**. In the northern hemisphere, it is called the aurora borealis. You might have heard it called by its common name, the Northern Lights.

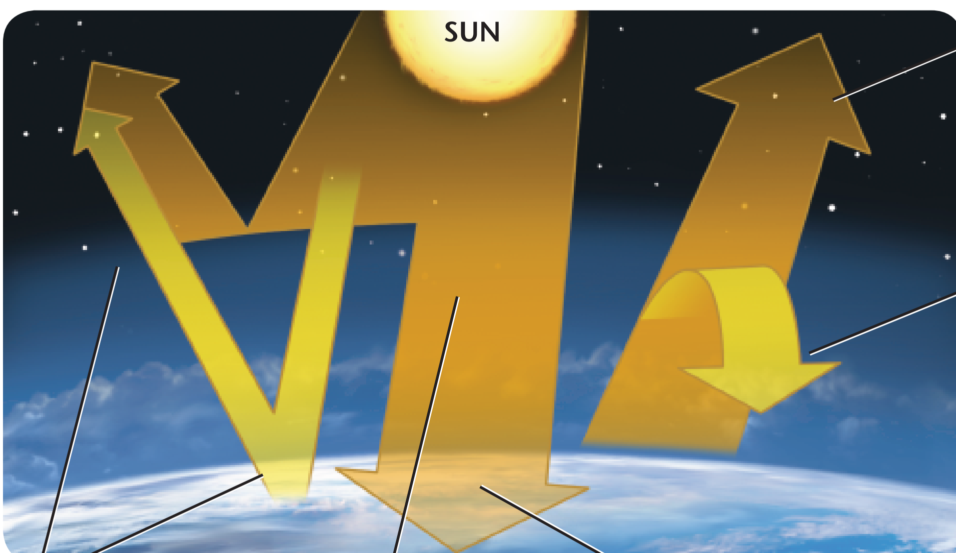
aurora: light shows in Earth's upper atmosphere created by solar wind

Figure 3.8 This photo shows an aurora.

The Link between the Atmosphere and Life

Green plants and other producers need light from the Sun for photosynthesis. And consumers need plants. So without the Sun, there would be no life. But too much sunlight is not a good thing, either. Sunlight includes bands of energy that are harmful to living things. These include UV (ultraviolet) rays and X rays. Fortunately, ozone and other gases in the atmosphere interact with incoming energy from the Sun to protect us. In effect, our atmosphere acts like a filter that helps to shield living things from much of the Sun's harmful effects.

Figure 3.9 shows that Earth's atmosphere also helps to trap heat from the Sun that would otherwise escape back into space. This helps to keep Earth at just the right temperature for life to thrive. Without this atmosphere, extreme fluctuations of temperature would make life as we know it impossible. Moderate temperatures also allow water to exist in all three states on Earth—gas, solid, and especially liquid. Earth is the only known planet with this unique combination, which is a key factor for maintaining life.



▲ **Figure 3.9** Earth's atmosphere acts like a blanket that traps heat as it escapes back into space. Instead, the heat is redirected toward the surface again. This helps to keep temperatures within a stable range for life.

LEARNING CHECK

1. Refer to **Figure 3.9**. Explain how the atmosphere protects Earth.
2. In your notebook, create a graphic organizer that explains an aurora.
3. Predict what would happen to life on Earth if the magnetosphere disappeared. Justify your answer.

ACTIVITY LINK
Activity 3.9, on page 194

The Moon is our nearest neighbour in space.

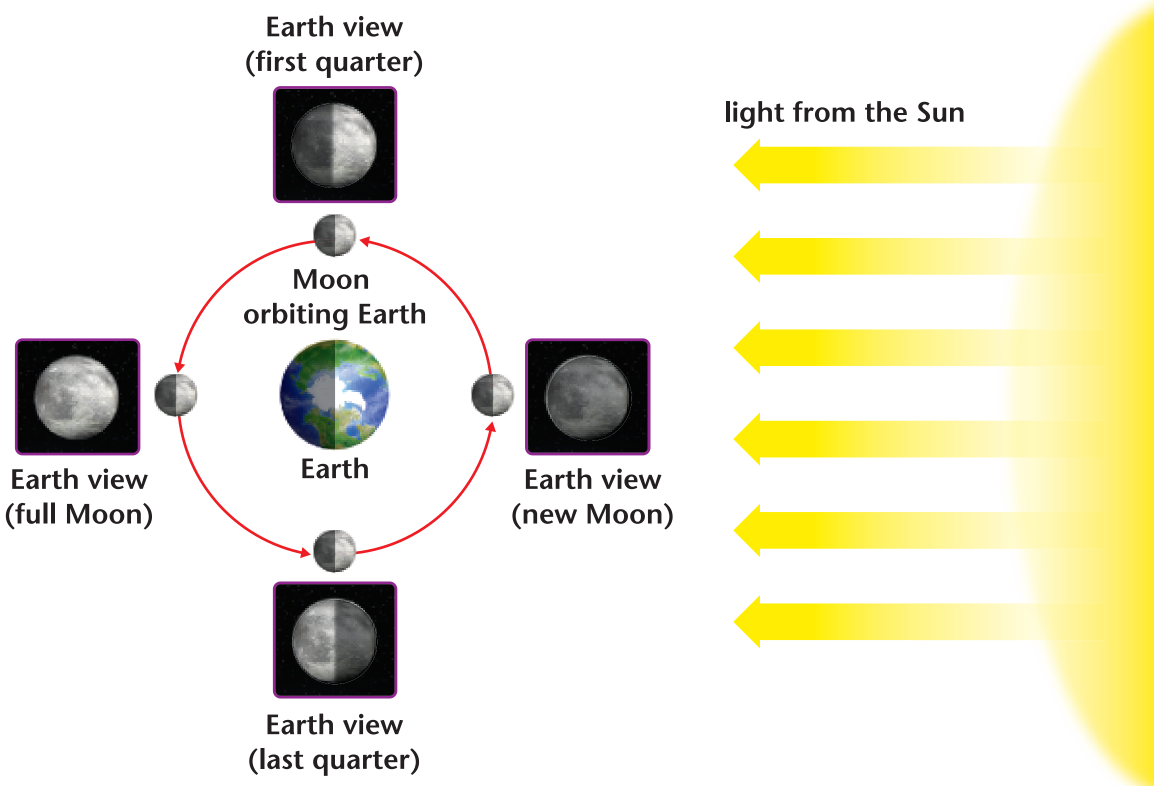
Our calendar and holidays are linked to the appearance of the Moon in the night sky. The Moon also affects the lives of animals. Some aquatic animals, for instance, mate or lay their eggs when the Moon becomes more full or less full. Even some of our language comes from words for the Moon. The word month (think of it as "moonth") is one example. The word lunar, which means moon, gives us the word lunatic.

Phases of the Moon

The Moon looks like it shines with a light of its own, but looks can be deceiving. Moonlight is really sunlight that reflects from the Moon's surface.

The reflected light we see is always from the same side of the Moon. The reason involves how the Moon rotates (spins) and how the Moon orbits. It takes the Moon 27.3 days to make one full orbit around Earth. It also takes the Moon 27.3 days to make one full rotation. The rotation rate and the orbiting rate match, so we always see the same side of the Moon from Earth. The other side of the Moon—called "the dark side of the Moon"—always faces away from us, so we never see it.

The lit-up side of the Moon is always fully lit up, but we can't always see the whole lit-up side. Instead, we see changes in the amount of lit-up surface during a month: the phases of the Moon. **Figure 3.10** shows how the Moon, Earth, and Sun are arranged to produce the phases of the Moon.



▶ **Figure 3.10** The phases of the Moon are caused by the amount of lit-up surface that we can see from Earth as the Moon orbits our planet.

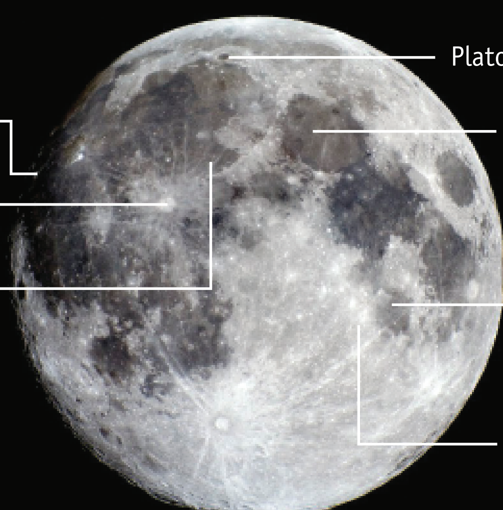
Research Focus

Activity 3.7

MORE ABOUT THE MOON

There's plenty about the Moon to explore, even if only from Earth. Here are some things you could investigate. Present your findings in a format of your choosing, or use the template provided by your teacher.

1. What superstitions are associated with the Moon?
2. How many vehicles (rovers) have travelled on the Moon, who drove them, and what was their source of power?
3. Many surface features have names with water in them, such as Sea of Crisis, Lake of Dreams, and Swamp of Decay. But there has never been water on the Moon. What's up with that?
4. Many craters are named for people in Earth's history such as Pythagoras, Abu Arrayhan Muhammad ibn Ahmad al-Biruni, H. G. Wells, Dmitri Mendeleev, and Marie Curie. Who are they, and why are they famous or important?
5. What are some songs and poems that have been written about the Moon? What role does the Moon play in them?



We have observed and imagined the Moon's face for as long as there have been people to do so. The dream to visit and set foot upon the Moon became a reality on July 20, 1969.

MONDO MOON

Average distance from Earth: 384 400 km (0.003 AU)

Size (Diameter): 3475 km (almost one-quarter of Earth's)

Temperature Range: −170°C to 100°C

Time for One Rotation: 27.3 days

Time for One Orbit: 27.3 days

Atmosphere: none

Symbol: ☾

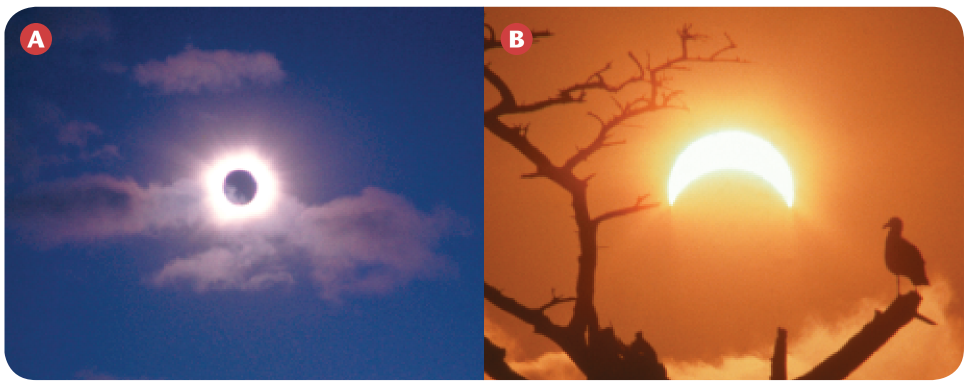
LEARNING CHECK

1. Explain why we cannot see the "dark side" of the Moon.
2. Refer to **Figure 3.10**. In your notebook, draw a labelled sketch showing the phases of the Moon.
3. What conditions make it difficult to live on the Moon?

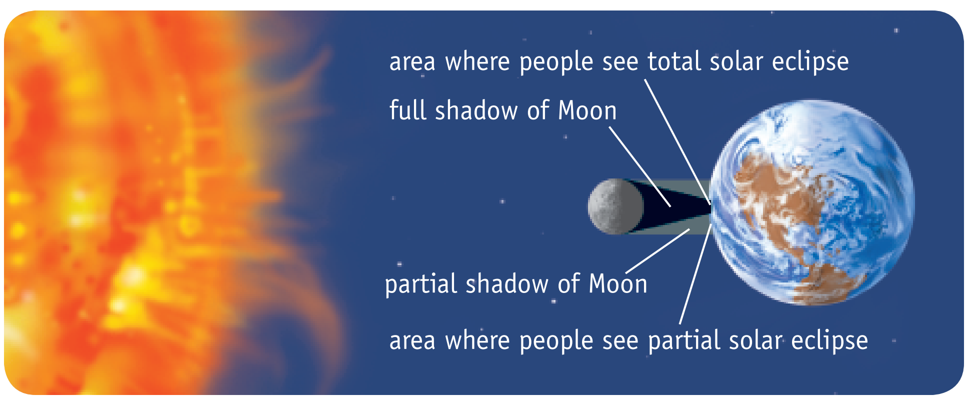
The Sun, Moon, and Earth interact to create eclipses.

An eclipse occurs when Earth or the Moon is lined up in space so that it blocks the Sun's light for a short time. There are two kinds of eclipses: solar eclipses and lunar eclipses.

Solar Eclipses



▶ **Figure 3.11** During a total solar eclipse (shown in A), the Moon covers the whole face of the Sun, leaving only a hazy, white glow of the Sun's atmosphere visible, like a halo. During a partial solar eclipse (shown in B), the Moon covers only part of the Sun's face.



▶ **Figure 3.12** Positions of the Sun, Moon, and Earth during a solar eclipse. (Sizes and distances in the diagram are not drawn to scale.)

solar eclipse: an event where the Moon moves directly between the Sun and Earth, so that the Moon casts its shadow on part of Earth

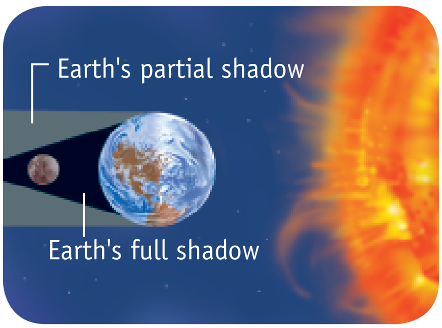
In a **solar eclipse**, the Moon moves directly between the Sun and Earth, so that the Moon casts its shadow on part of Earth. Solar eclipses occur in the day, and the Sun's light is either totally or partially blocked. Your location determines whether you see a total or partial solar eclipse (**Figure 3.11**).

If you are standing in the area covered by the full shadow of the Moon, you see a total solar eclipse. If you are standing in the area covered by part of the shadow of the Moon, you see a partial solar eclipse. Refer to **Figure 3.12**. Many people flock to sites around the world to view solar eclipses when they occur. A solar eclipse is best viewed through a telescope or other lens equipped with a solar filter. **Danger!** *Never look directly at the Sun, either during the eclipse or any other time. The Sun's energy can damage or destroy the parts of the eye that enable you to see, causing blindness.*

Lunar Eclipses

A **lunar eclipse** occurs when Earth moves directly between the Sun and Moon, so that Earth casts its shadow on the Moon. Refer to **Figure 3.13**. During a total lunar eclipse, the Moon is covered fully by Earth's shadow. Sometimes this shadow appears red due to light bending in Earth's atmosphere. During a partial lunar eclipse, Earth's shadow only partially covers the Moon. Lunar eclipses are more common than solar eclipses. You can watch a lunar eclipse safely, because you are looking at reflected sunlight, not the direct energy of the Sun.

lunar eclipse: an event where Earth moves directly between the Sun and Moon, so that Earth casts its shadow on the Moon



◄ **Figure 3.13A** During a total lunar eclipse, the whole Moon passes through the full shadow cast by Earth. During a partial lunar eclipse, only a part of the Moon passes through the full shadow cast by Earth.

▲ **Figure 3.13B** During a total lunar eclipse, Earth's shadow totally covers the face of the Moon.

LEARNING CHECK

1. Refer to **Figures 3.12** and **3.13**. Draw the arrangement of the Sun, Earth, and Moon during a solar and a lunar eclipse.
2. Compare a total solar eclipse to a partial solar eclipse.
3. Write an announcement warning people about the danger associated with a solar eclipse.

Inquiry Focus

Activity 3.8

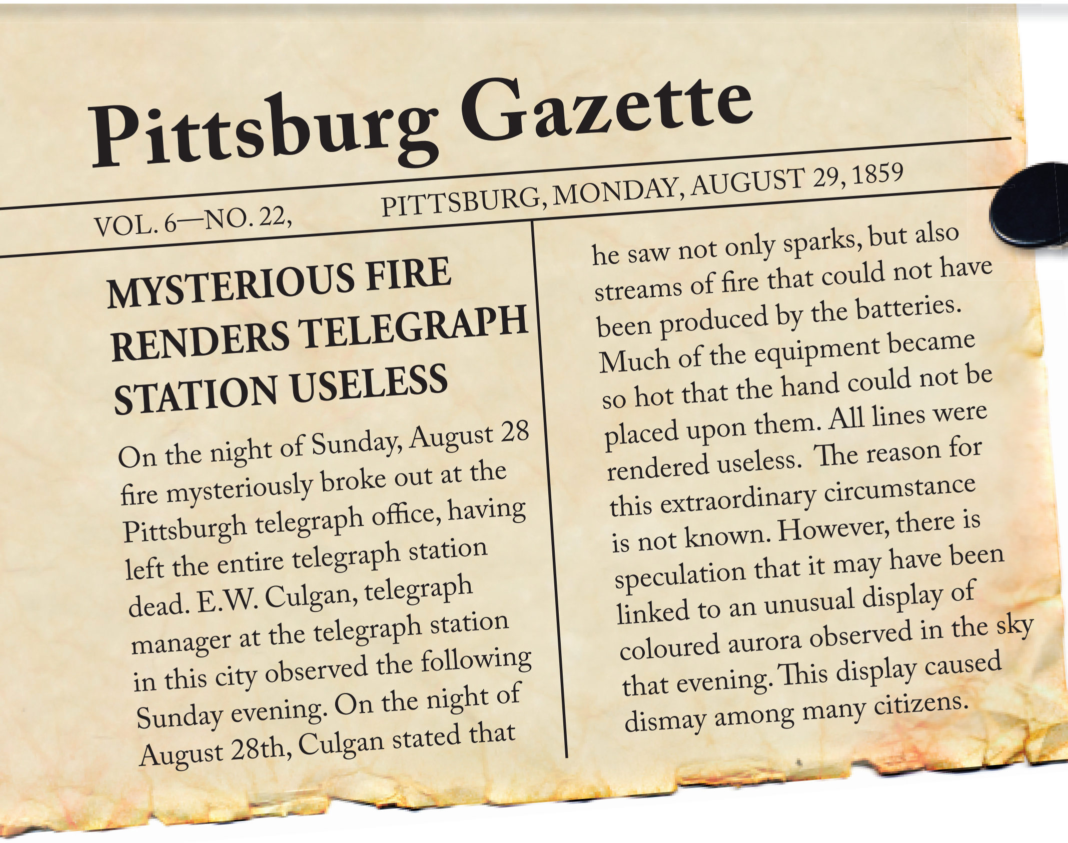
MODELLING ECLIPSES

Use the diagrams on these two pages to help you design models that show where the Sun, Moon, and Earth are in space during a solar eclipse and a lunar eclipse. Your model will need a light source to be the Sun, a globe for Earth, and a smaller ball for the Moon.

What Did You Find Out?

1. What is it that blocks light during a solar eclipse? During a lunar eclipse?
2. A lunar eclipse can only take place during a full moon. Use your model to explain why.
3. Use your model to explain why there isn't a lunar eclipse with every full moon.
4. Explain why more people on Earth can see a lunar eclipse than a solar eclipse.

Case Study Investigation: Solar Storms



Pittsburg Gazette

VOL. 6—NO. 22, PITTSBURG, MONDAY, AUGUST 29, 1859

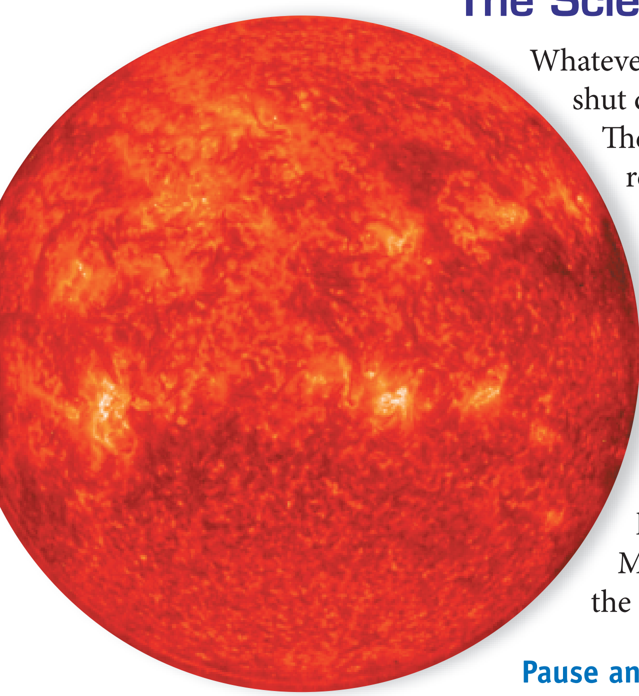
MYSTERIOUS FIRE RENDERS TELEGRAPH STATION USELESS

On the night of Sunday, August 28 fire mysteriously broke out at the Pittsburgh telegraph office, having left the entire telegraph station dead. E.W. Culgan, telegraph manager at the telegraph station in this city observed the following Sunday evening. On the night of August 28th, Culgan stated that he saw not only sparks, but also streams of fire that could not have been produced by the batteries. Much of the equipment became so hot that the hand could not be placed upon them. All lines were rendered useless. The reason for this extraordinary circumstance is not known. However, there is speculation that it may have been linked to an unusual display of coloured aurora observed in the sky that evening. This display caused dismay among many citizens.

▲ An electrical telegraph machine. Sent along telegraph lines linking different stations, telegraph messages composed of Morse code electrical signals are an indispensable form of modern, long distance communication.

The Science Behind the Story

Whatever happened on this mysterious night in August, 1859, it shut down telegraph communications across much of the world. The first clue to what was going on came from instruments recording Earth's magnetic field around the globe. The planet's magnetism had suddenly gone off the chart. The cause? A powerful storm raging on the Sun's surface. Explosions known as solar flares ejected super-hot gases from the Sun's surface. Magnetic bubbles of matter burst from the Sun's upper layer, hurling solar particles toward Earth at millions of kilometres per hour. It lasted six days and was the fiercest magnetic storm in recorded history. Classified as a solar superstorm, the magnetic storm of 1859 knocked out electrical communication around the globe. Magnetic compasses went haywire. Brilliant auroras coloured the skies from Canada to the Caribbean.



▲ Large solar flares were observed during the 1859 solar super storm.

Pause and Reflect

1. Describe how the solar superstorm of 1859 affected Earth.
2. Explain what occurs on the Sun's surface during a solar storm.

How would a solar storm affect Earth today?

▲ Auroras are rarely seen in the southern United States, but in 1859 they were visible to people as far south as the Caribbean.

A solar storm of this size has not been seen since 1859. Since then, technology has advanced in leaps and bounds. How might a solar superstorm affect modern telecommunications and global power grids? Would you believe you might not be able to send a text message, listen to the radio, or even flush your toilet? Here are just a few ways a solar superstorm could affect Earth today:

- **Communications Down:** Telecommunications could be knocked out as solar particles break down satellite solar panels and electronic equipment. In 2003, the Sun released the largest solar flare in history. If this flare had been aimed at Earth, it would have knocked out telecommunications worldwide.
- **Power Out:** Power grids across the world could be affected. In 1989, a small solar storm brought down the Hydro-Québec power grid. A solar superstorm could cause continent-wide black outs for a day or longer, affecting food storage, transportation, emergency services, and even the flow of water into your home.
- **Radio Disruption:** A solar superstorm could interfere with radio signals. This would affect aircraft communications and the Global Positioning System (GPS).

Pause and Reflect

3. Describe three ways a long-term power outage could affect your daily life.

Investigate Further

4. What are telecommunications? Choose one example of a telecommunications device and find out how it might be affected by a solar storm.
5. Learn more about the 1989 Québec power outage.
   - Why did the power grid fail?
   - For how long was the power out?
   - How was the problem fixed?
6. Find out how airline travel could be affected by a solar storm.
7. Imagine that you are a reporter for a national newspaper when a solar superstorm strikes. Write a news report covering the effects of this storm in today's world.

Inquiry Focus

Activity 3.9

COLONY ON ANOTHER PLANET

One reason we explore space is to learn about other planets. If one of these planets is enough like our own, it may be a site for a future human colony. In this activity, you will explore what makes Earth so well suited for the existence of life. You will then use this knowledge to assess if humans could survive on another planet.

What To Do

1. Work with a partner to create a list of conditions that you think make Earth suitable for life. Share your list with another set of partners and add any new ideas to your list.
2. Read the description of the planet in the white box below.
3. With your partner, make a list of reasons why this planet might be able to support human life. Compare this list to your list from step 1.

Planet Loki

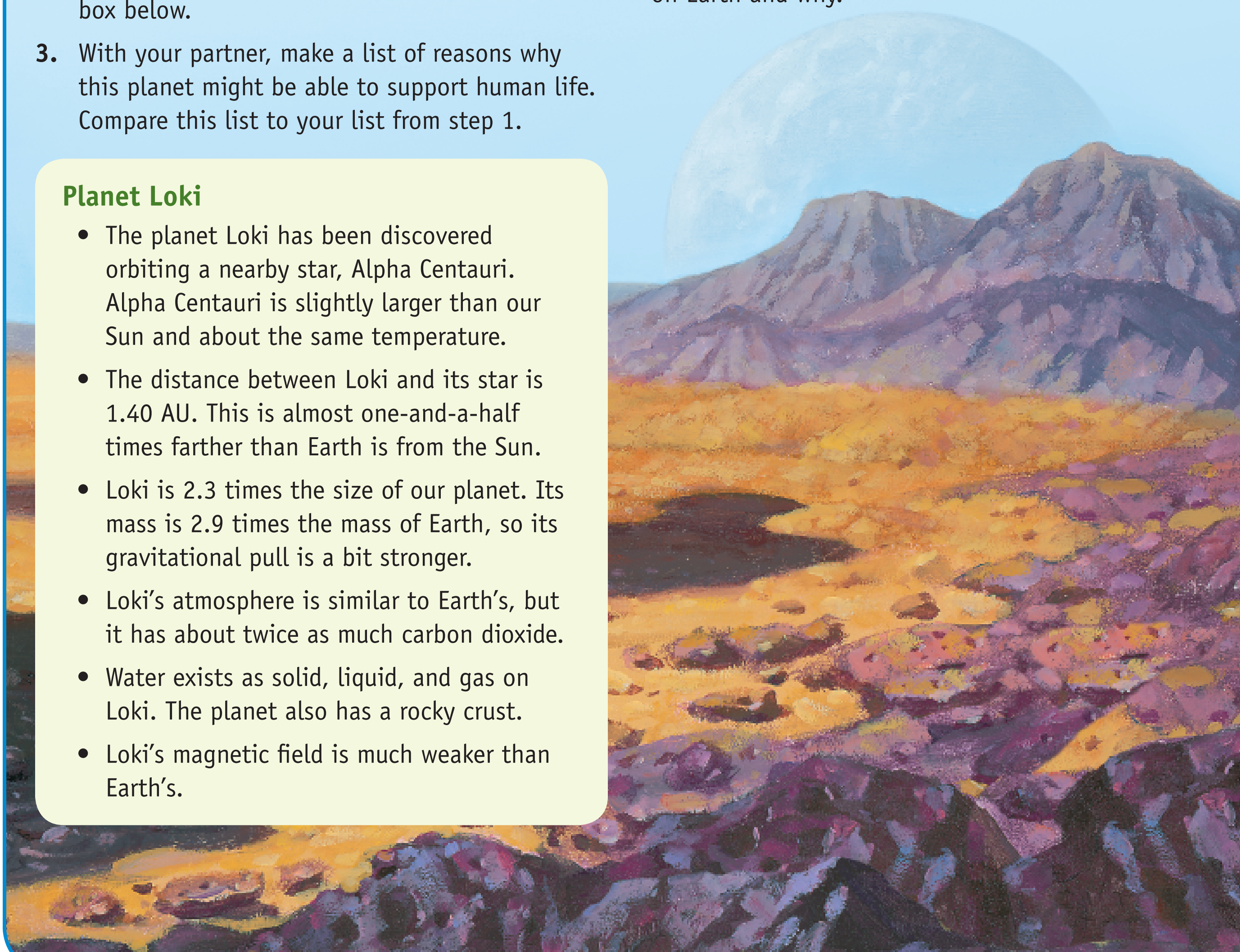
- The planet Loki has been discovered orbiting a nearby star, Alpha Centauri. Alpha Centauri is slightly larger than our Sun and about the same temperature.
- The distance between Loki and its star is 1.40 AU. This is almost one-and-a-half times farther than Earth is from the Sun.
- Loki is 2.3 times the size of our planet. Its mass is 2.9 times the mass of Earth, so its gravitational pull is a bit stronger.
- Loki's atmosphere is similar to Earth's, but it has about twice as much carbon dioxide.
- Water exists as solid, liquid, and gas on Loki. The planet also has a rocky crust.
- Loki's magnetic field is much weaker than Earth's.

What Did You Find Out?

1. Use a Venn diagram or double bubble organizer to compare Earth and Loki.
2. Do you think Loki is a suitable planet to set up a human colony? Explain why or why not.
3. Do you think plants on Loki would be able to carry out photosynthesis? Why or why not?

Inquire Further

Imagine that life already exists on Loki. Construct an alien life form that might be found on Loki using art material or a computer program, or draw it on paper. Explain how it would differ from or be similar to life on Earth and why.



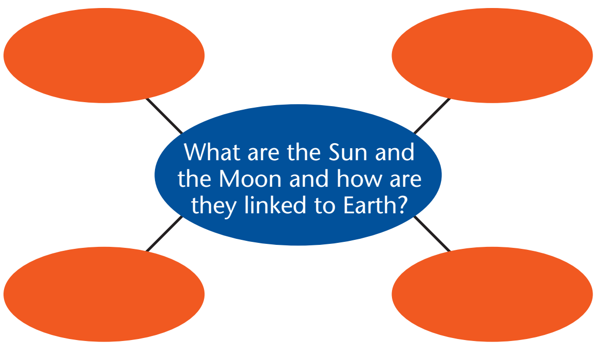
Topic 3.2 Review

Key Concepts Summary

- The Sun is our nearest star.
- Interactions of Earth and the Sun make life possible.
- The Moon is our nearest neighbour in space.
- The Sun, the Moon, and Earth interact to create eclipses.

Review the Key Concepts

1. K/U Answer the question that is the title of this topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples from the topic using key terms as well as your own words.



2. C Refer to **Figure 3.12** and **Figure 3.13A**. Use words, pictures, or a graphic organizer such as a Venn diagram to compare the similarities and differences between a total solar eclipse and a total lunar eclipse.
3. A The *aurora borealis,* or “northern lights,” have been described in stories by many different Aboriginal peoples. Use your school’s library to compare several stories about the aurora borealis told by North American Aboriginal peoples. Briefly summarize these stories in your own words.
4. T/I Predict why the surface of the Moon is covered with thousands of craters while there are very few craters on Earth’s surface today.
5. C Refer to **Figure 3.10**. In your notebook, draw and label a diagram that models the phases of the moon. Write a caption for your diagram that explains why we can’t always see the entire lit-up side of the Moon.
6. T/I Predict what might happen to Earth if the Moon broke out of its orbit.
7. C Use the diagram below to explain the Sun’s role in sustaining life.